MINING THE MARS ATMOSPHERE. John E. Finn[1] and K. R. Sridhar[2], [1]Regenerative Life Support Branch, NASA Ames Research Center, Moffett Field CA 94035, USA, (jfinn@ mail.arc.nasa.gov), [2]Aerospace and Mechanical Engineering, Tucson Arizona 85721, USA, (sridhar@shakti.ame.arizona.edu)

A series of concepts have been developed to mine the atmosphere of Mars and process it to extract or generate compressed carbon dioxide, compressed buffer gas mixtures of nitrogen and argon, water, oxygen, carbon monoxide, and/or carbon. Such products can be of use to science instruments, robotic, and human missions. The products can be for utility purposes, life support, propulsion (both interplanetary and on the planet's surface), and power generation.

The concepts rely on separation, compression, and reaction unit operations. The basic proposed process for separation and compression of Mars gases is based on temperature-swing adsorption. Using the diurnal temperature swing on the surface of Mars as the primary source of energy, the relatively low pressure (6–15 mbar) atmosphere can be compressed to higher pressures (1–2 bar) using an adsorption/ desorption cycle as shown in Figure 1. Higher pressures and mass throughputs are possible if additional heat (such as waste heat from other chemical processes or power plants) is available. Separation of a nitrogen and argon mixture (~4 volume percent of the atmosphere) occurs simultaneously and out of phase with the compression process.

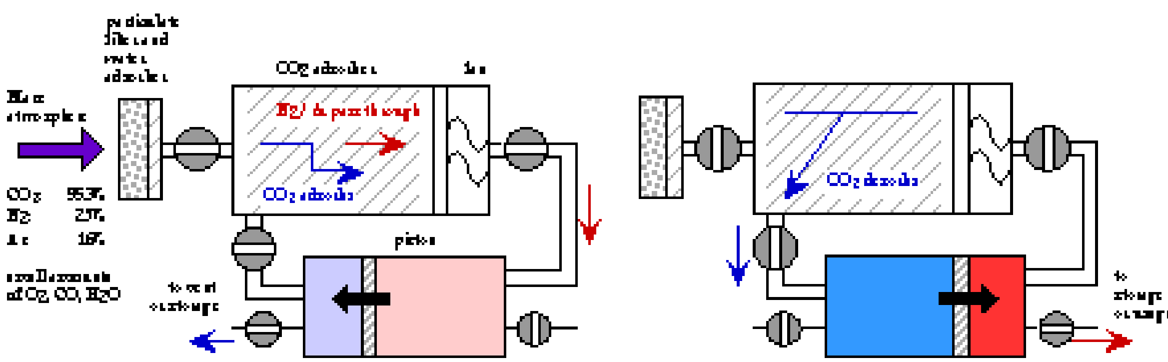

Fig. 1. Simplified schematic of an adsorption-based process for production of compressed pure CO_2 and N_2/Ar gas from the Martian atmosphere. At **left**, the atmosphere is drawn under cold nighttime conditions through a column that selectively adsorbs CO_2 while N_2/Ar passes through and is collected. At **right**, the column warms under daytime conditions and desorbs CO_2 at elevated pressure. In this drawing, the CO_2 is used to compress the N_2/Ar mixture.

The feasibility of both separation and compression processes have been demonstrated in the laboratory under simulated Mars temperatures, pressures, and composition (1). Candidate materials (Figure 2) have been identified and their compression performance has been studied in the laboratory (2).

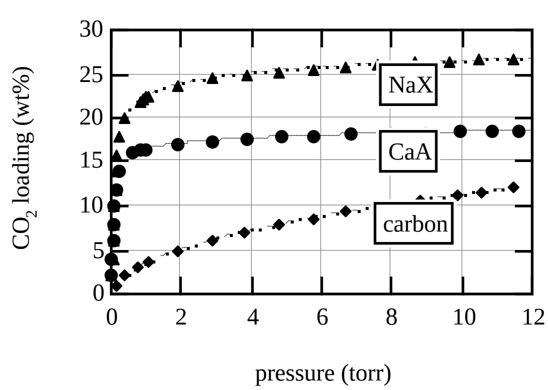

Fig. 2. A series of isotherms obtained at NASA Ames Research Center for CO_2 adsorption on various materials at 200K at Mars surface pressures. Loading data at low and high temperature ranges are used to design adsorption compressors (from ref. 2).

Separation and compression steps can be combined with reaction steps, such as solid oxide electrolysis of CO_2, to form plant designs which are capable of producing a range of useful products from Martian atmospheric raw material. These include the following:

Compressed carbon dioxide: There are several uses for the compressed CO_2 utility gas. In science instruments they can be used to blow dust off optics and instrument interiors, clean specimens, etc. In robotic missions they can be used, among other things, to blow dust off solar panels, inflate panels and structures, give propulsive thrusts to unjam stuck mechanisms, and provide the “feed stock” for propulsion generation plants. In manned missions, the gas can be used for the above applications as well as oxygen generation for life support, and for plant growth chambers. They can also be used as a means of providing the “green-house gas” for an enclosed Mars dome.

Nitrogen and argon mixtures: The gases can be used as a carrier gas in instruments, buffer gas for life support, and as a source of nitrogen for other chemical processes (production of ammonia for example).

Oxygen generation: Oxygen can be produced from the predominantly carbon dioxide atmosphere by a process called solid oxide electrolysis. In this solid state process oxygen and carbon monoxide are produced from the feed gas of carbon dioxide. Oxygen thus produced can be used for propulsion and/ or life support.

Carbon monoxide: Carbon monoxide is the byproduct of the CO_2 electrolysis process. This “fuel” can be used to advantage for Mars surface propulsion, and as a fuel to operate a regenerative fuel cell in the night, if the electrolysis is performed during the day with photovoltaic cells. In this manner, the same CO_2 electrolyzer stack hardware will perform as a fuel cell during the night (an energy storage device with high efficiency).

Carbon: Carbon can be produced by disproportionating the carbon monoxide to produce solid carbon and CO_2 . If this process is added to the electrolyzer, the end products of the combined process would be solid carbon and oxygen. Carbon can be used as a fuel, or as valuable carbon fiber that will be used to build reinforced fiber composites.

Water: The small amounts of water present in the atmosphere can be mined using a temperature swing adsorption process. The volume of air that needs to be processed to obtain significant amounts of water is quite high in most locations.

Since the planetary materials required for the above processes come from the atmosphere that is relatively homogeneous, this concept can be site independent as long as it is on the surface of Mars. Most of the processes described here require very little, if any, electrical energy. The primary source of energy for most of the processes comes from the diurnal temperature swing on the surface. Most of the components involved in these processes are solid state, i.e., they have very few moving parts and hence, inherently more reliable. The solid oxide electrolysis technology can be used to extract oxygen in the carbothermal or hydrogen reduction process used for LUNOX from regolith (commonalty of technology for Moon and Mars ISRU).

References: (1) Finn, J. E., Sridhar, K. R., and McKay, C. P., “Utilisation of Martian atmosphere constituents by temperature-swing adsorption,” *Journal of the British Interplanetary Society*, 49 (11), p.423-430 (1996). (2) Finn, J. E., Sridhar, K. R., and McKay, C. P., "Martian atmosphere utilization by temperature swing adsorption", Paper No. 961597, presented at the 26th International Conference on Environmental Systems, Monterey, California, July 1996.